Spontaneous Arousals in Supine Infants While Swaddled and Unswaddled During Rapid Eye Movement and Quiet Sleep

Claudia M. Gerard, MD; Kathleen A. Harris; and Bradley T. Thach, MD

ABSTRACT. *Objective.* **Supine sleep is recommended for infants to decrease the risk of sudden infant death syndrome, but many parents report that their infants seem uncomfortable supine. Many cultures swaddle infants for sleep in the supine position. Swaddled infants are said to "sleep better"; presumably they sleep longer or with fewer arousals. However, there have been no studies of the effect of swaddling on spontaneous arousals during sleep. Arousal is initiated in brainstem centers and manifests as a sequence of reflexes: from sighs to startles and then to thrashing movements. Such "brainstem arousals" may progress to full arousal, but most do not.**

Methods. **Twenty-six healthy infants, aged 80 ± 7 days, were studied during normal nap times. Swaddled (cotton spandex swaddle) and unswaddled trials were alternated for each infant. Sleep state (rapid eye movement [REM] or quiet sleep [QS]) was determined by behavioral criteria (breathing pattern, eye movements) and electroencephalogram/electrooculogram (10 infants). Respitrace, submental and biceps electromyogram, and video recording were used to detect startles and sighs (augmented breaths). Full arousals were classified by eye opening and/or crying. Frequencies of sighs, startles, and full arousals per hour were calculated. Progression of events was calculated as percentages in each sleep state, as was duration of sleep state.**

Results. **Swaddling decreased startles in QS and REM, full arousal in QS, and progression of startle to arousal in QS. It resulted in shorter arousal duration during REM sleep and more REM sleep.**

Conclusions. **Swaddling has a significant inhibitory effect on progression of arousals from brainstem to full arousals involving the cortex in QS. Swaddling decreases spontaneous arousals in QS and increases the duration of REM sleep, perhaps by helping infants return to sleep spontaneously, which may limit parental intervention. For these reasons, a safe form of swaddling that allows hip flexion/abduction and chest wall excursion may help parents keep their infants in the supine sleep position and thereby prevent the sudden infant death syndrome risks associated with the prone sleep position.** ***Pediatrics*** **2002;110(6). URL: http://www.pediatrics.org/cgi/content/full/110/6/e70;** ***sudden infant death syndrome, sighs, startles.***

ABBREVIATIONS. SIDS, sudden infant death syndrome; REM, rapid eye movement; QS, quiet sleep; EMG, electromyogram; EEG, electroencephalogram; EOG, electrooculogram.

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Supine sleeping decreases the risk for sudden infant death syndrome (SIDS).[1] However, some parents place their infants in the prone sleep position despite these recommendations.[2–4] Many of these parents state that their infants seem more comfortable when prone and sleep better.[4] Studies confirm that the prone position decreases frequency of arousals.[5–9]

Swaddled infants placed on their backs are said to "sleep better," presumably meaning that they sleep longer or with fewer arousals. Parents commonly report that infants who are back sleepers "startle themselves awake." Experimental studies confirm that arousals to stimuli decrease during swaddled sleep; however, the effect of swaddling on spontaneous arousals during supine sleep has not been studied.[10]

Arousal, initiated in brainstem centers, is manifested as a sequence of reflexes.[11] These begin as sighs and may progress to startles. These startles may or may not progress to full arousal. Supine sleeping is associated with increased arousals from sleep compared with the prone sleep position.[5–9] The effect of swaddling on the frequency of brainstem arousals as well as full behavioral arousals is unknown. Likewise, the effect of swaddling on progression of brainstem arousals to full arousals is unknown.

METHODS

Design

Infants were alternately swaddled in a cotton spandex swaddle (Fig 1) or not swaddled and left in the free state. After sleep was attained, the infant was observed for rapid eye movement (REM) sleep and quiet sleep (QS).

Setting

Infants were studied during a daytime nap in a sleep laboratory. The Washington University Human Study Committee approved the study protocol, and informed consent was obtained from the parent of each infant before the study.

Participants

We studied 26 healthy infants, 16 girls and 10 boys. The mean age was 80 ± 7 days, with a range of 24 to 180 days. All infants were normal by clinical examination. Two infants were preterm, both at 32 week estimated gestational age.

Intervention

The infant was alternated to the opposite period—swaddled or free—and observed again for both sleep states. When infants awoke during the study, they were lulled back to sleep with routine measures—rocking, pacifier, singing, or feeding—or the study was completed.

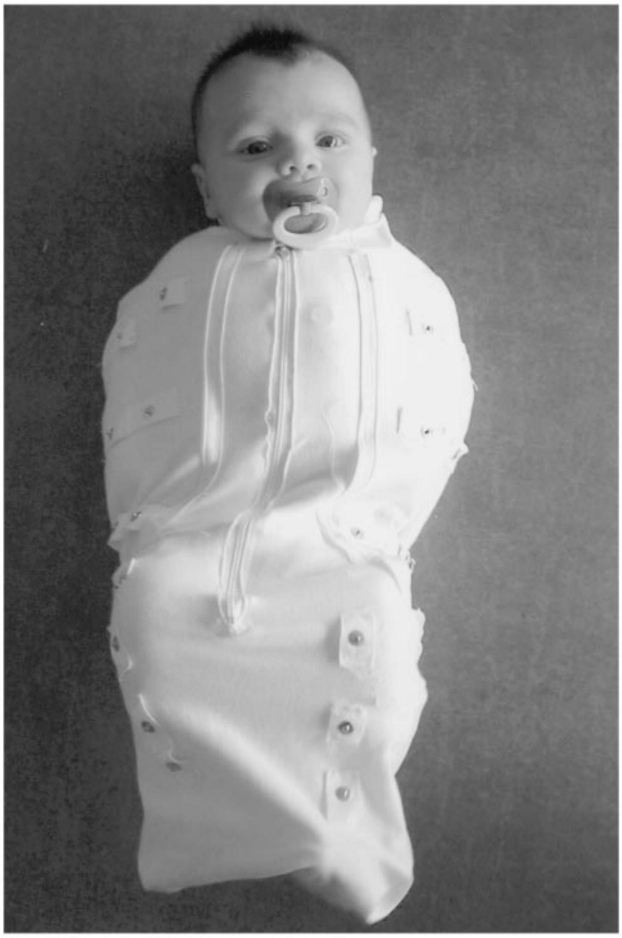

Fig 1. The study swaddle is made of a cotton spandex material with a center zipper to unswaddle/swaddle without waking the infant and snaps at side and bottom to adjust to the size of the infant. The swaddle allows hip flexion/abduction and chest wall excursion. Arms are restrained at the side with loose internal restraints.

All infants underwent a single polysomnographic recording with data recorded on an 8-channel polygraph recorder (model R611; Beckman Instruments, Schiller Park, IL). Each infant was monitored with electrocardiogram. Thoracic and abdominal respiratory movements and the sum of these two recordings were measured using inductance plethysmography (Respitrace; Ambulatory Monitoring, Ardsley, NY). Oxygen saturation was monitored with pulse oximetry (Nellcor Pulse Oximetry, Hayward, CA) with the probe placed on the right or left great toe. Electromyogram (EMG) was monitored on the right bicep with 2 superficial electrodes. Submental EMG was monitored with 2 electrodes. Electroencephalogram (EEG) was used with the O2 and CZ electrode placement (10 infants). Electrooculogram (EOG) was determined with electrodes at the superior and inferior orbital rims (10 infants).

A video recording was made throughout each study. Two separate cameras (JVC Professional Products, Elmwood Park, NJ) simultaneously recorded the infant and the respiratory channels of the polygraph. The images were combined and displayed on a split-screen monitor (Videonix, Campbell, CA) so that the events on the polygraph and the behavior of the infant could be viewed simultaneously.

Outcome Measures

Sleep state was determined by behavioral criteria (breathing pattern and eye movements) in all infants.[12] EEG/EOG criteria in combination with behavioral and respiratory criteria were used to determine sleep state in 10 infants. Determination of sleep state by behavioral and respiratory criteria correlated with the EEG/EOG determination of sleep state with 97% agreement when 1 reviewer used behavior and respiratory criteria alone and the other reviewer, blinded to the infant's behavior, used EEG/EOG criteria alone. Sighs (ie, augmented breaths) were detected by Respitrace. Startles were detected by biceps EMGs and by video recording (Fig 2). Full arousals consisted of eye opening and/or crying (Fig 3). Frequencies of sighs, startles, and full arousals per hour were calculated to normalize the data for comparison across infants. For avoiding biasing the data, the final behavioral arousal sequence was not included in data analysis. This was done because 5 infants were not allowed to wake spontaneously at the end of the study but were awakened because of time constraints. The progression of sighs to startles and startles to full arousal are expressed as a percentage. The total duration of sleep states was calculated for each infant during each period, discounting arousals <2 seconds. The percentage of brief arousals, those <1 minute, were compared

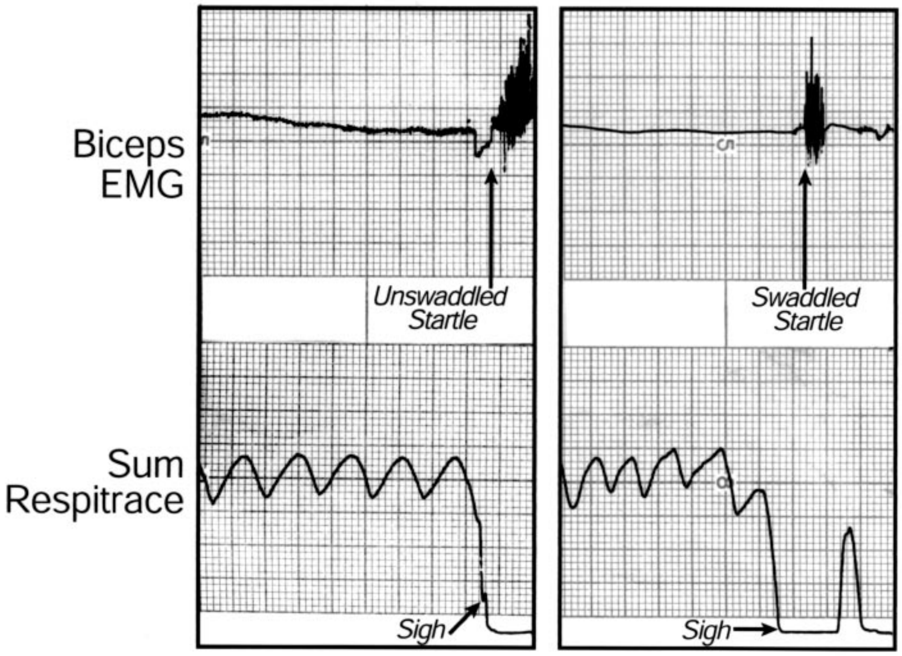

Fig 2. Tracing of a startle on respiration (inspiration down) and biceps muscle EMG in 1 infant when unswaddled and swaddled.

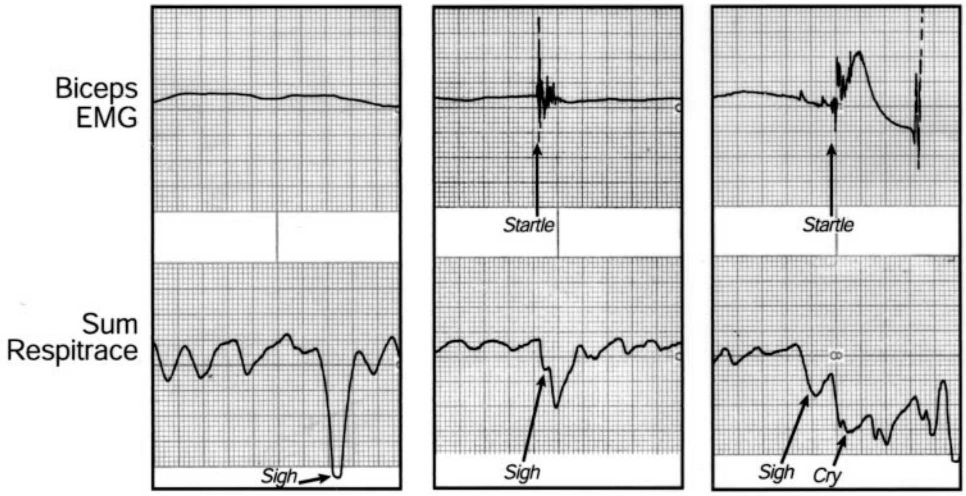

Fig 3. Tracings of respiration (inspiration down) and biceps EMG shows 3 stages in progression of the arousal response. The first panel shows a sigh alone. The second shows a sigh accompanied by a startle, and the third shows a sigh, startle, and full arousal.

in swaddled versus unswaddled periods during REM sleep. Data are expressed as mean ± standard error of the mean. The Wilcoxon signed-rank test was used for statistical analysis for nonparametric data.

RESULTS

Twenty-six infants had QS during unswaddled and swaddled periods. Twenty-two infants had REM sleep during both periods. The average study duration was 107 ± 7 minutes (range: 58–178 minutes). No infants escaped from the swaddle despite increased motor activity when awake. The frequency of sighs per hour was unchanged when swaddled during both QS and REM sleep (Figs 4 and 5). The frequency of startles was decreased with swaddling during QS ($P < .02$) and REM sleep ($P < .005$; Figs 4 and 5). The frequency of behavioral arousals was decreased with swaddling during QS ($P < .001$) but not REM sleep (Figs 4 and 5). The progression of sighs to startles was decreased in both QS and REM sleep by swaddling ($P < .003$ and 0.0004; Figs 6 and 7). The progression of startles to full arousal was decreased with swaddling in QS but not REM sleep ($P < .006$; Figs 6 and 7). The percentage of brief arousals was statistically increased during swaddled compared with unswaddled periods in REM sleep ($P < .05$; Figs 6 and 7). The average sleep duration while swaddled was increased in REM sleep ($P < .0005$; Fig 8). There was no difference in duration between the periods in QS ($P > .05$; Fig 8).

DISCUSSION

The Back to Sleep Campaign with the American Academy of Pediatrics' recommendation has reduced SIDS deaths by nearly 50%.[1] Unfortunately, approximately 20% of parents change their infants to the prone sleep position by 2 months of age, the age when SIDS risk is greatest.[4] Many parents reported that they made this change because their infants slept better or seemed more comfortable when prone.[3,4]

Swaddling has been used for centuries as an infant care practice throughout much of the world. The common theme of swaddling is motor restraint. Infants who are swaddled for sleep are also placed supine. Women who traditionally swaddle their infants report that their infants would not sleep if they were not swaddled.[13] It is unclear what effect swaddling exerts on infants, but it does seem that swaddling an infant results in "better sleep" than leaving the infant unswaddled, as this study suggests.

The safety of traditional swaddling methods is concerning. Prospective trials have linked tight swaddling with the legs in extension and adduction with increased incidence of congenital hip dysplasia.[14] Therefore, a swaddling technique that allows hip flexion and abduction is important. Other reports have linked tight chest swaddling with increased risk for pneumonia.[15] Thus, a swaddle that allows chest excursion is necessary. The current blanket swaddling technique used in the United States is

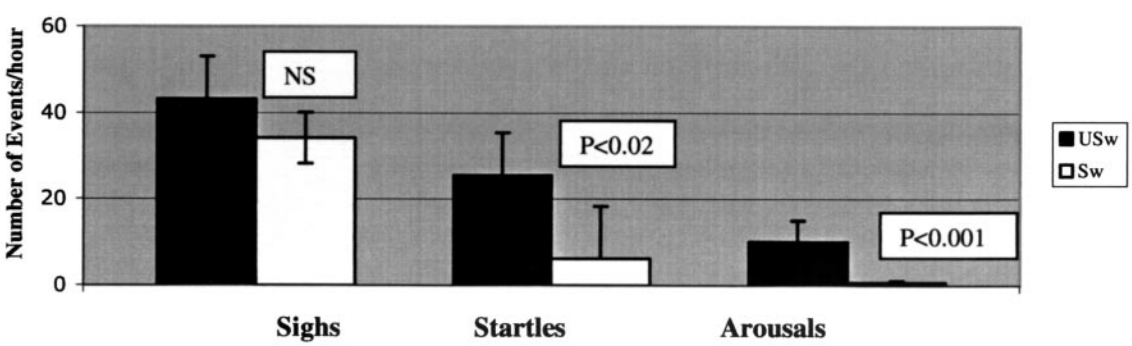

Fig 4. Frequency of events during QS sleep while unswaddled and swaddled.

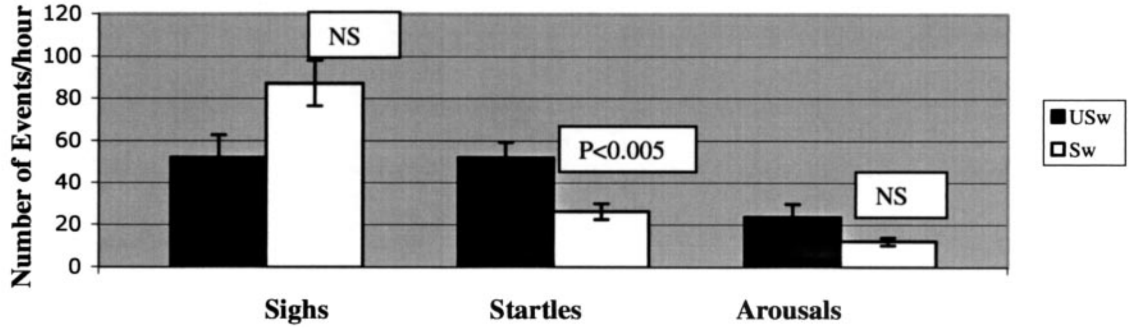

Fig 5. Frequency of events during REM sleep while unswaddled and swaddled.

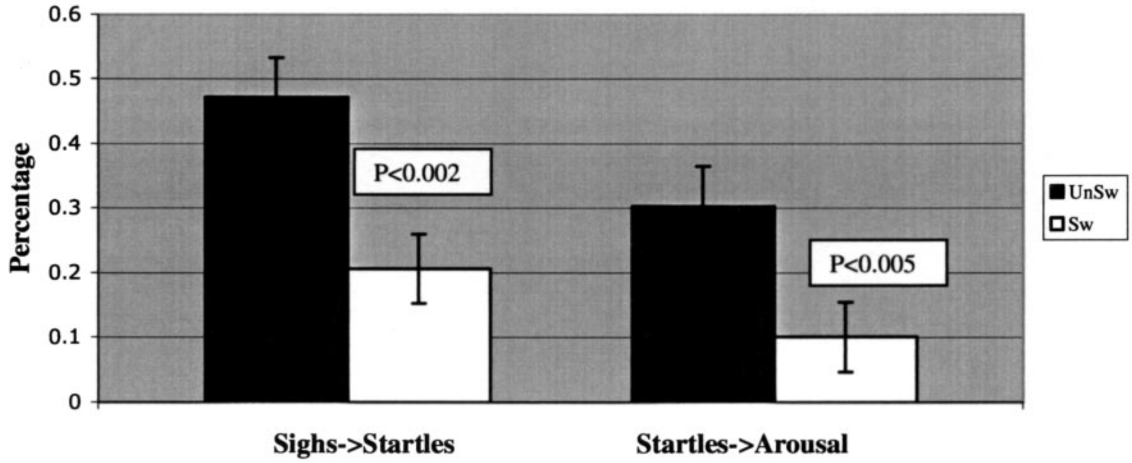

Fig 6. Percentage of events that progressed to the next level of arousal in QS sleep during unswaddled and swaddled periods.

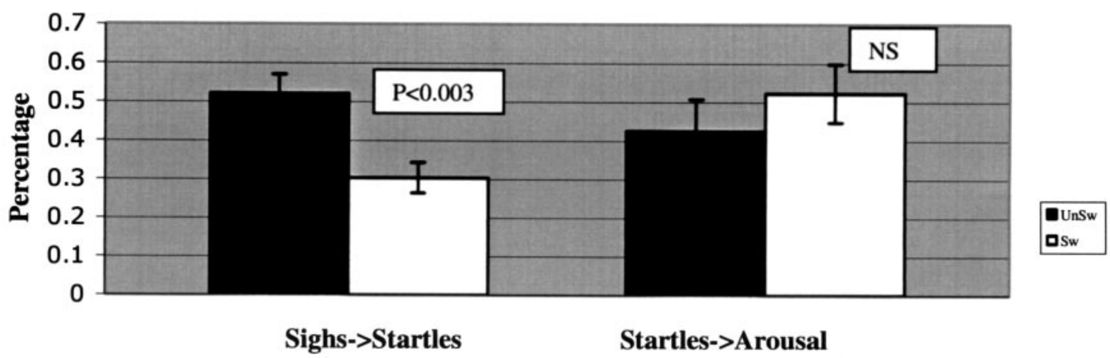

Fig 7. Percentage of events that progressed to the next level of arousal in REM sleep during unswaddled and swaddled periods.

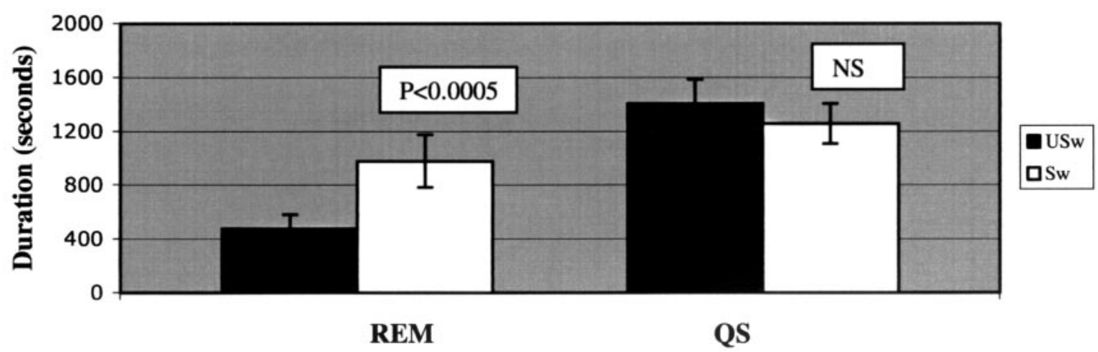

Fig 8. Duration of REM sleep and QS during unswaddled and swaddled periods.

problematic in that older and larger infants can escape, resulting in a free blanket in the bed with the resultant head-covering risk for SIDS. Therefore, a technique that limits breaking free from the swaddle is also important. These points should be remembered with any discussion on swaddling. Noteworthy is that no infants we studied escaped from the swaddle that we designed for this study.

Epidemiologic studies suggest that swaddled and supine sleeping infants have a significantly lower risk for SIDS than unswaddled supine sleeping infants.[16,17] This decreased risk may derive from the motor restraint of swaddling keeping infants from rolling to a prone position and preventing them from getting their heads caught in loose blankets.[16] Fewer arousals during swaddled supine sleep may also prevent infants from attempting to get into a wedged, head-covered, or prone position.

A comparison of unswaddled prone sleep and swaddled supine sleep would be interesting in the study of the arousal pathway progression because prone sleep is associated with decreased behavioral arousals.[5–9] Prone sleep may inhibit arm movements associated with a full extensor startle response, which would lead to less frequent behavioral arousal by reducing proprioceptive stimuli in the same way that may occur during swaddling. Decreased arousability has been implicated as a cause for SIDS in prone sleeping infants. It is not known how swaddled supine sleeping arousability compares with prone sleeping arousability. As well, it is unknown whether swaddling might impair arousal in some life-threatening situations. However, epidemiologic studies clearly show that swaddling decreases the risk for SIDS more than supine sleeping alone.[16,17]

When interviewed, many parents have said that startles can cause full arousals in their infants. The present findings indicate that swaddling during QS inhibits each sequential step in the arousal pathway. It has been previously proposed that swaddling inhibits full arousal by limiting the movement and proprioceptive stimulation of startles.[10,18,19] A similar explanation was expressed by Sherrington[20] for "chained reflexes" in which the motor activity of the initial reflex serves as a stimulus for the next reflex in the chain. This theory offers an explanation for our findings in QS; however, the theory alone cannot explain the observations in REM sleep. We found that during REM sleep, the infant is as likely to arouse from the startle when swaddled as when unswaddled. Why this is the case is unclear but may be related to previous observations. Normally, a significantly greater number of startles occur in REM than in QS.[21] Furthermore, it has been shown that repeated arousal stimuli leads to a more rapid inhibition of the arousal pathway in REM sleep than in QS.[22] The first evidence of habituation is a decrease in the number of startles that progress to full arousal. We found that infants have more startles in REM sleep when unswaddled than when swaddled. It follows that both arm movements and associated proprioceptive stimulation would be increased in unswaddled infants. It could be that unswaddled infants, during REM sleep, habituate to the increased frequency and magnitude of this proprioceptive stimuli to a greater extent than when swaddled. Such habituation would lead to a reduction in overall behavioral arousals that follow startles when unswaddled. This would have the effect of reducing the difference in behavioral arousals in unswaddled and swaddled infants. In any case, full arousals were shorter in duration when swaddled than unswaddled, which resulted in the infant's returning to sleep more rapidly.

It should be pointed out that the startle-arousal proprioceptive theory has limitations in that it does not explain our other finding that progression of sighs to startles is inhibited by swaddling in both sleep states. Why this is so is unclear as proprioceptive stimuli associated with a sigh seem unlikely to be affected by swaddling.

Unlike QS duration, swaddling was associated with more REM sleep in this study. The increased REM sleep duration during swaddling likely is related to briefer arousals, allowing the infant to return to sleep more rapidly. Why a swaddled infant would have shorter arousal durations is not clear. The motor restraint of swaddling may limit additional movements, which could reduce the proprioceptive stimulation to the reticular activating system. Breaking the cycle of motor activity and associated proprioceptive stimulation could allow the infant to return to sleep.

The long-term effect of longer REM sleep duration in swaddled infants is unclear but may be beneficial. It has been suggested that REM sleep directs early brain maturation through control of neural activity.[23] REM sleep may also play a role in protein synthesis and with the learning and memory processes.[24,25] REM sleep deprivation may correlate with hyperactivity as well as depression.[26,27]

CONCLUSION

Infants who sleep supine have decreased awakenings during QS when swaddled. During REM sleep, behavioral arousals are unchanged but the infant is more likely to return to sleep on his or her own. This would reduce the need for parent intervention in helping an infant return to sleep. Therefore, a safe form of swaddling, that does not restrict hip movement or chest wall excursion and limits breaking free, may help parents decide to keep their infants in the supine sleep position and thereby prevent the additional risk of SIDS with prone sleeping.[28]

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